System Design: The Human Factor
Attention, Workload and Alarms – Keeping Patients Safe

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Overview

- **Part 1:**
  - *Human Factors – what it is and what it means*
  - *Examples of human factor lessons from aviation*
- **Part 2:**
  - *Alarms: A specific example of a problem and an approach to a solution*

What is Human Factors

- Ergonomics (physical and cognitive) – fitting the task to the person
- Engineering – interface design, device design
- Psychology – how people understand the world around them; how people interact with machines
- Anthropology / Ethnography – work analysis, and the effects of tools on people's activities

Human Factors (HF) is Needed When:

- Humans and machine working together closely
- High tech systems
- Complex, tightly coupled environments

Common in aviation, computer science (usability), nuclear power, process control, space, etc.

HF creates safe, easy to use technology

Human Factors at the University of Maryland Medical System

- Developing a Center for Patient Safety
  - *Using video as a tool for patient safety*
    - *Performance evaluation*
    - *Development of best practices*
    - *Web-based tutorials*
  - *Using technology to enhance coordination and information flow for care providers*
  - *Advanced displays for patient safety*

How to design a CRIS

- "Human error in medicine, and the adverse events which may follow, are problems of psychology and engineering not of medicine."
  - *John Senders, 1993*

- *In designing a CRIS, you are designing a partner with whom you will work every day*

What kind of partner to work with?

- Strong, silent type
- Interrupting
- Know-it-all
- Bossy
- Stubborn

- Communicative, but not intrusive
- Knowledgeable
- Team player
- Cooperative

Choosing the right partner can make life safe and easy or difficult and dangerous

Aviation Example 1: Autopilot

- China Air A300 crashed in 1994 on final approach, killing over 200 people
- Automation was engaged to help get pilots on track for landing, and automation "decided" to "go around" instead of landing
- Pilot and automation were competing for control. Automation was not communicating with pilot.

Aviation Example 2: FMS

- In 1992, A320 crashed on final approach to Strasbourg, France airport, killing 87 of the passengers and crew.
- Flight Management System (FMS), which helps the pilots manage the aviation systems, was implicated.
  - *FMS had switched to Vertical speed (V/S) mode from of flight path angle (FPA) mode*
  - *Pilots entered "3.3" and descended 3300 feet per min instead of 3.3 degree slope (800 ft/min)*

Why did these accidents happen?

- **Multiple causes, nearly always**
- **Difficult flight flight – high workload**
  - *bad weather, night time, change of runway, off course, navigation difficulties*
- **Automation was "strong silent type"**
  - *automation took actions unilaterally*
  - *small displays, minimal indicators did not communicate well with crew (display and input)*

Pharmacy Example: Generic Names

- **How does the CPOE system handle generic vs. trade drug-names?**
  - *e.g. Furosemide vs. Lasix*
- **What kind of partner?**
  - *Automatically change order to generic?*
  - *Only provide generic names?*
  - *Tell physician the generic name?*
- **Consider implications:**

Good technology design can facilitate good human-to-human interaction

 http://hfrp.umm.edu

Alarms in patient monitoring equipment

- Technology can provide a safety net for better, safer, easier provision of care
- Poorly designed technology can increase risks, and frustrate users
- Auditory alarms associated with patient monitoring devices are a good example of well-intentioned technology application gone awry

Alarms: Appealing but Poorly Understood

Problems with Auditory Alarms:

- ***False alarm rates*** [2]
- ***Confusability***
- ***Non-diagnostic (Uninformative)***
- ***Disruptive, Workload increasing, Stress-inducing*** [6, 9]

Double-edged sword:

- **Alarms pose a threat to patient safety which must be addressed**
- **Can't eliminate: Despite problems, still serve many purposes**

What kind of partners are current alarm systems?

- Interruptive
- uniformative, uncommunicative
- know-it-all, but “dumb”
- No sense of context, no sense of priority

Better Design through Human Factors:

- Must provide users with critical information
- Current approach lacking, need better way
- Better equipment design is predicated on understanding the needs of the users
  - *For alarm design: information needs in monitoring patients*
- Medicine provides excellent paradigms for Human Factors techniques-- many parallels to other domains

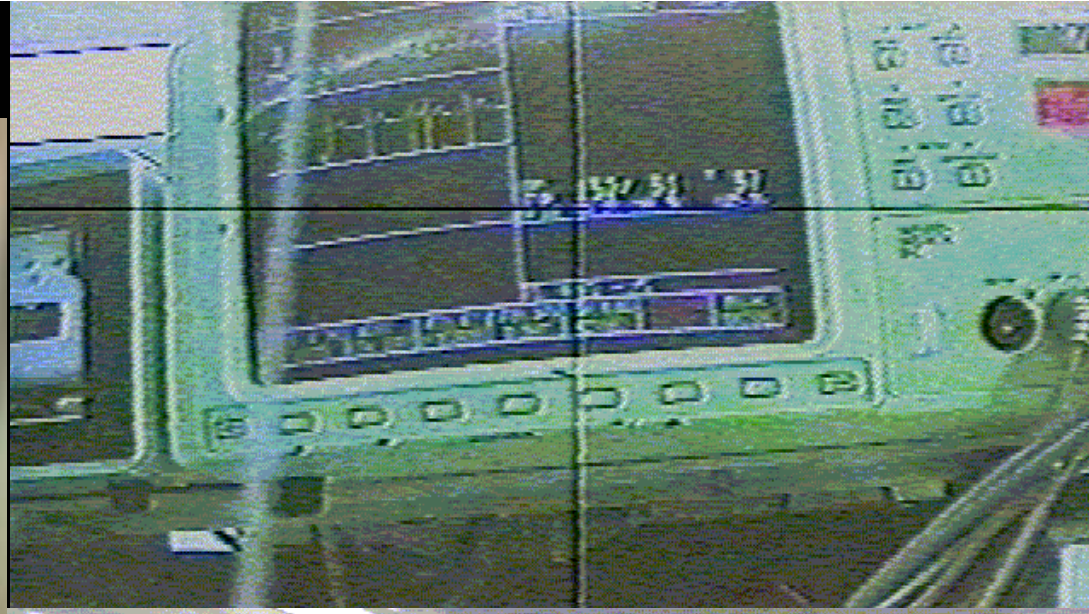
Laying a Foundation for Better Design

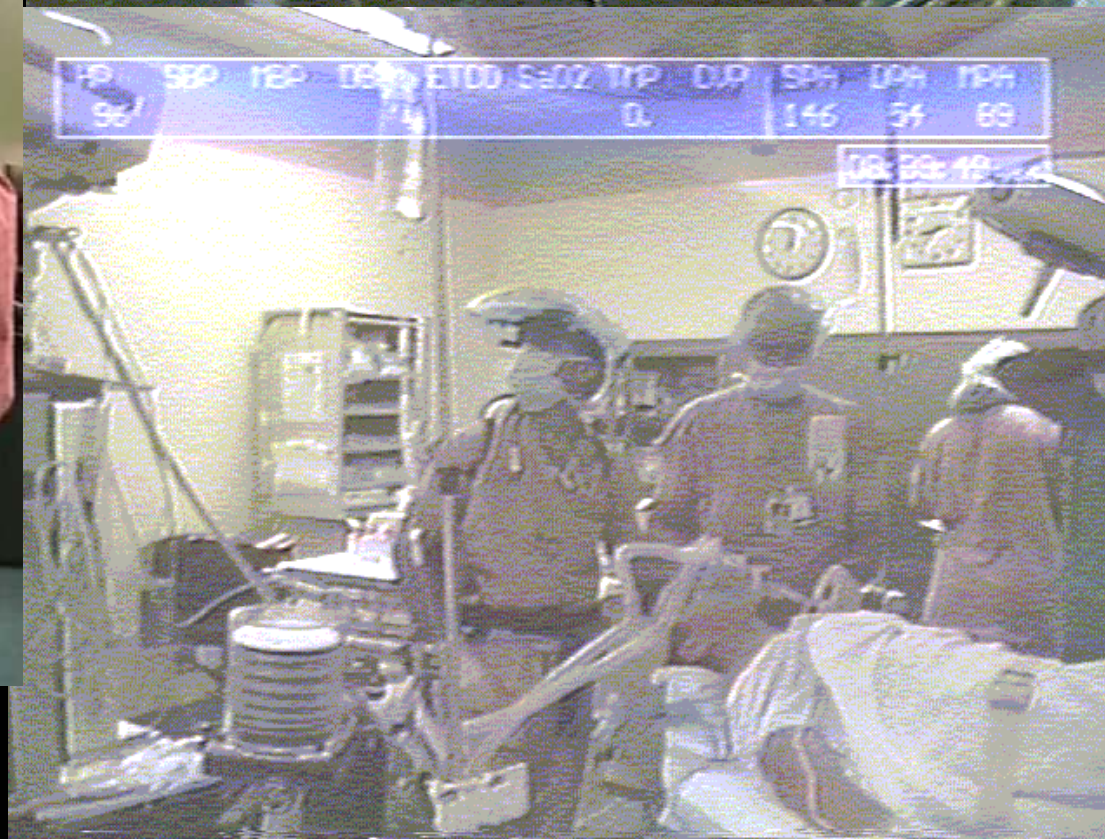
- There are few if any prospective studies of the effects of alarms *in situ* on monitoring behavior in patient care
- There is little if any research on information-seeking in patient monitoring

Question	***Relevant Study***
How do anesthetists seek information?	**Study 1**: Observe alarms in the operating rooms
How do current alarms affect performance?	**Study 2 & 3**: Experimental manipulation of alarms in operating room and high fidelity simulator
Is there a better way?	**Study 4**: Laboratory experiment on the auditory interface

Field Studies (Study 1): Observation of Anesthesia Domain

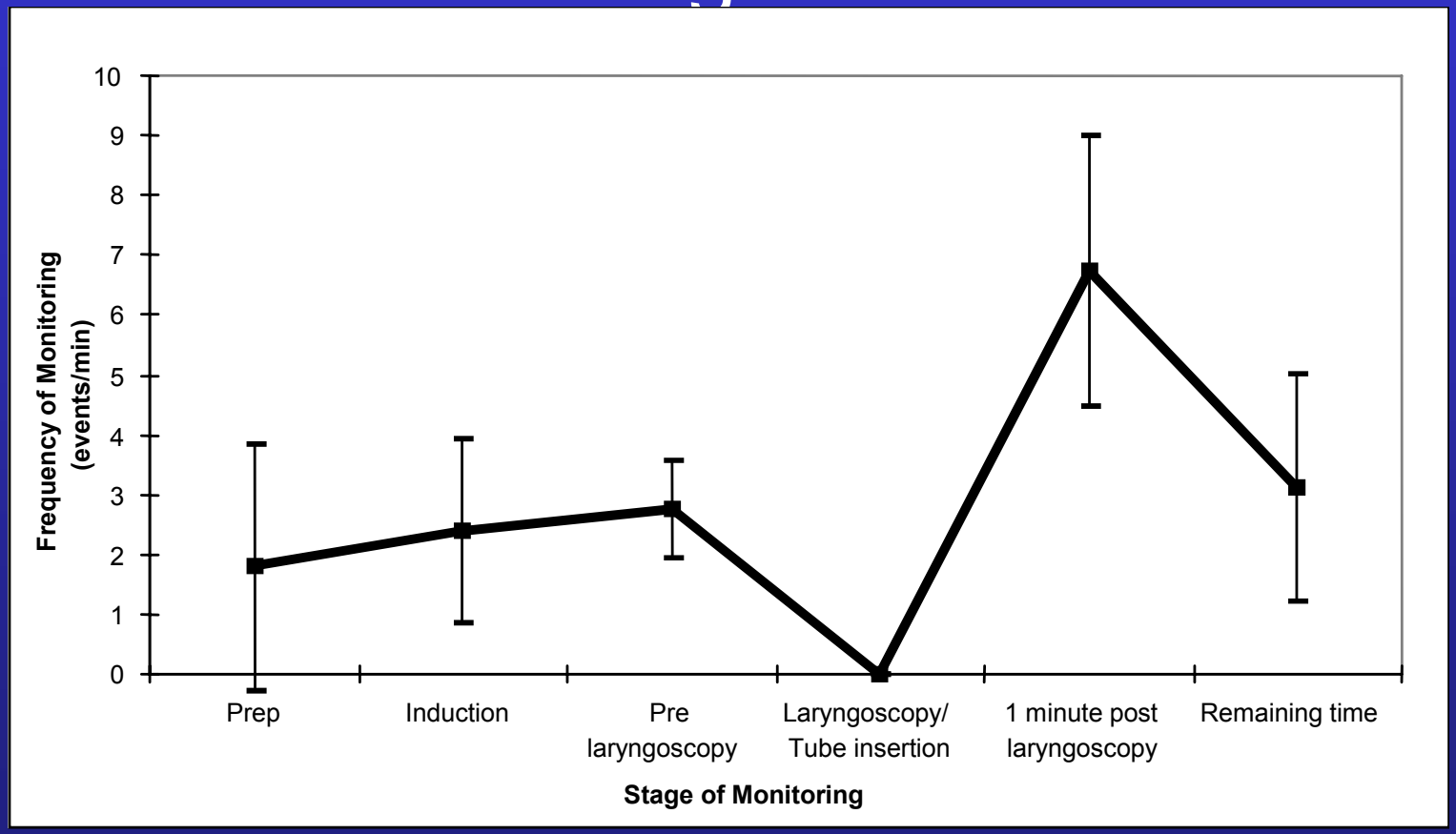
- **Using an eye tracker as tool for understanding information gathering [1]**
- **Anesthesiologists & nurse anesthetists wearing eye-tracker during airway management (no manipulations of alarms)**
  - *Allocation of visual attention to information sources analyzed*
  - *Visual trajectories examined*





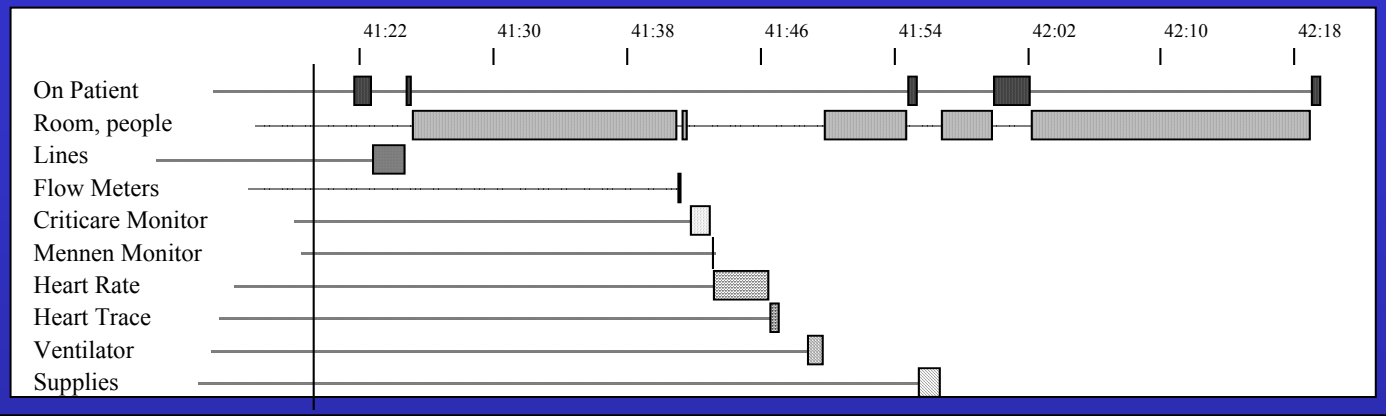
Patterns of Visual Sampling of Patient Monitors During Airway Management

[1]

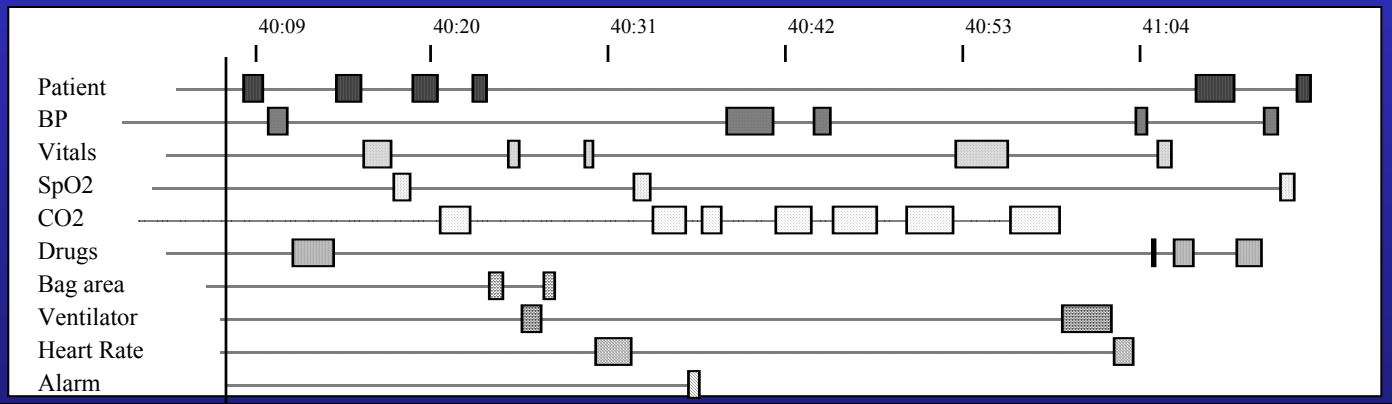


Taxonomy of Purposes for Monitoring[4]

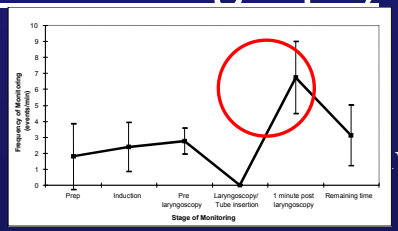
Routine Monitoring



Problem Solving



Historical Sense-making ("catching up")



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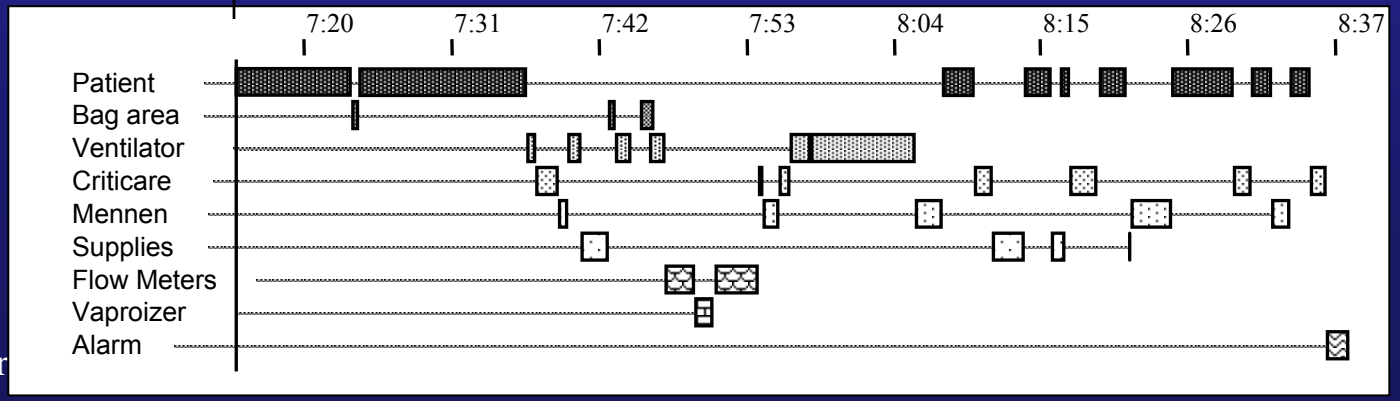


Conclusions of field observation

- Monitoring = spectrum of behavioral "modes" which influence response to alarms. [4, 5]
  - *Peripheral Monitoring Mode*
  - *Focal Monitoring Mode*
- Workload effects: Visually demanding task
- Eye tracker provides insight for Cognitive Task Analysis, which supports design of better equipment [12]

Studies 2 & 3: Effects of Alarms in Real ORs and High Fidelity Simulator

- Questions: Do alarms compete with direct patient care? And what information is pertinent?
- Manipulation: many alarms vs. fewer alarms
- In OR: "many alarms" condition led to slower task completion
- In Simulator: Eye tracking data show real human body (vs. mannequin) is an important information source in patient care [8, 10]

Searching for a Solution

- Problem: Care providers, visually taxed by patient care, are disrupted by alarms
- Candidate solution: Use auditory modality to present information, not just alarms --like Pulse Oximeter, but for more vital signs.
  - *Does not interrupt, continually available*
  - *Allows access to information when needed*
  - *Supports "peripheral monitoring"*
    - *Effective for monitoring of multiple vital signs as a single task (Loeb & Fitch, 2000)*

Will monitoring be effective when dividing attention between patient care and monitoring?

Cross-modal Theories of Monitoring

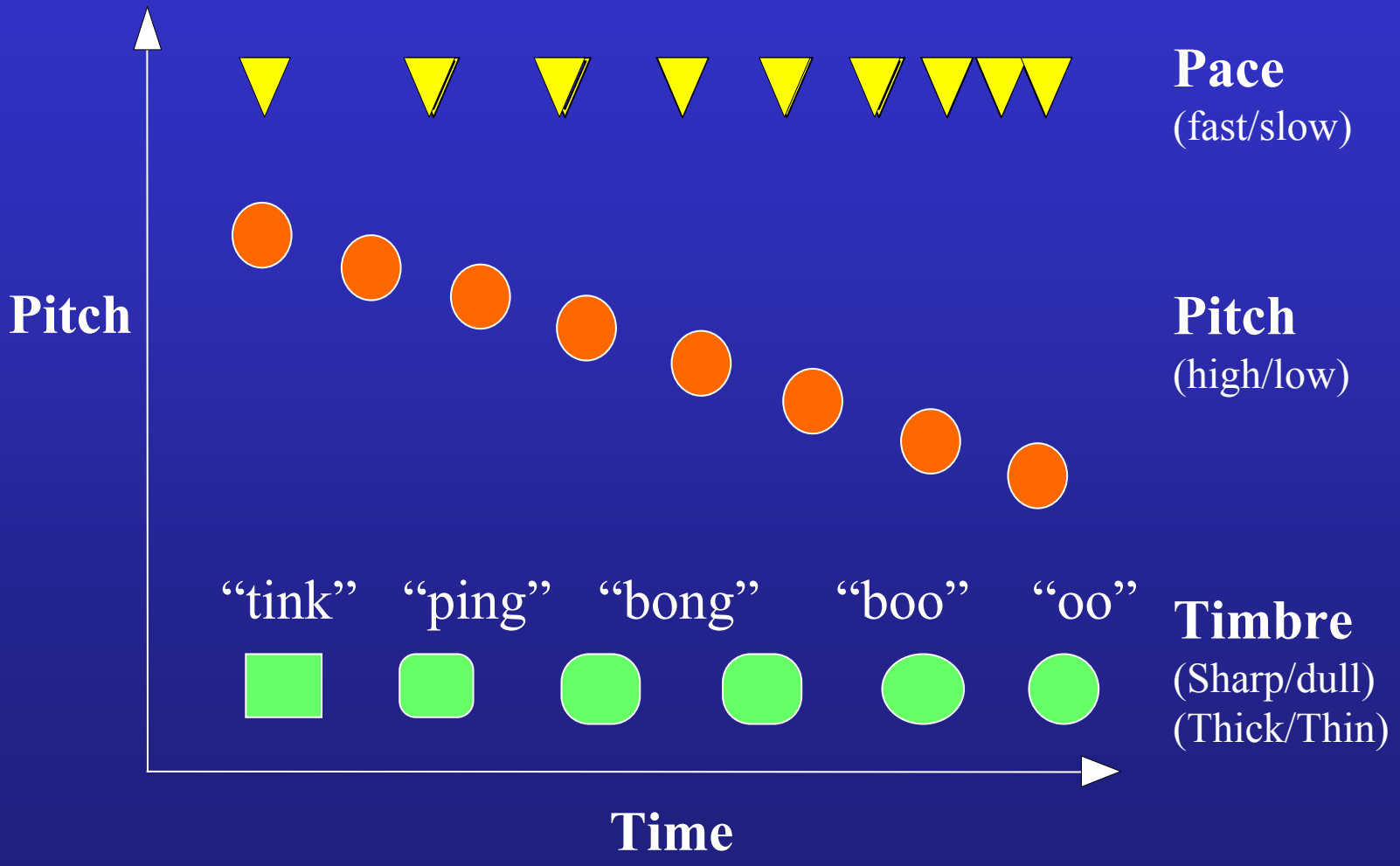
Cross-modal effects in dual task performance

- *spreading stimuli from two tasks across sensory modalities can be beneficial*

Cross-modal effects in redundancy gain

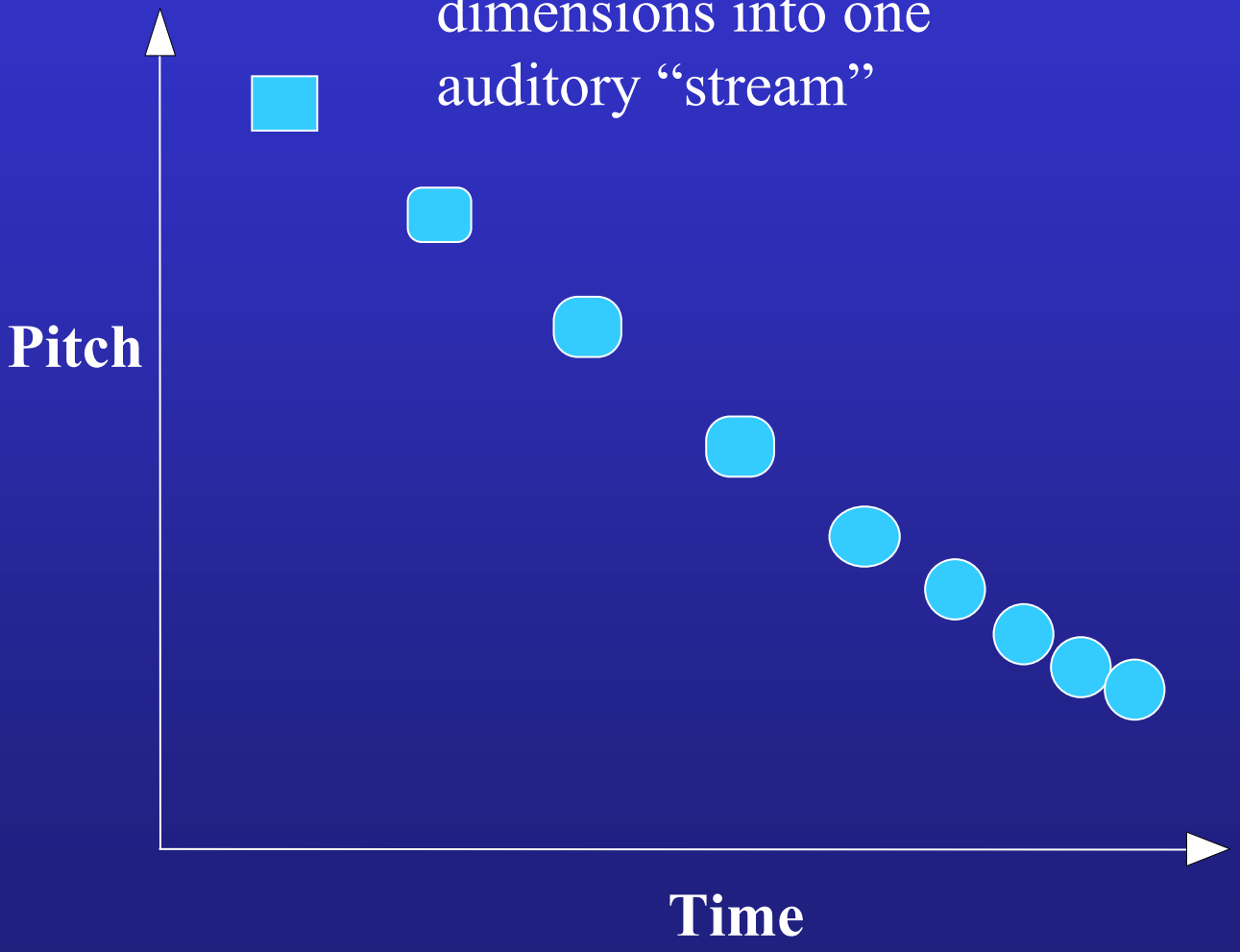
- *Bolstering a stimulus with information in a second, redundant dimension or modality can be beneficial*
- *Counter examples do exist*

Dimensions of Auditory Display



Dimensions of Auditory Display

Combine all three dimensions into one auditory "stream"



Pace
(fast/slow)

Pitch
(high/low)

Timbre
(Sharp/dull)
(Thick/Thin)

Auditory Display

- Using **pace**, **pitch** and **timbre** to communicate vital signs
- Two streams of sound, each containing three dimensions of information

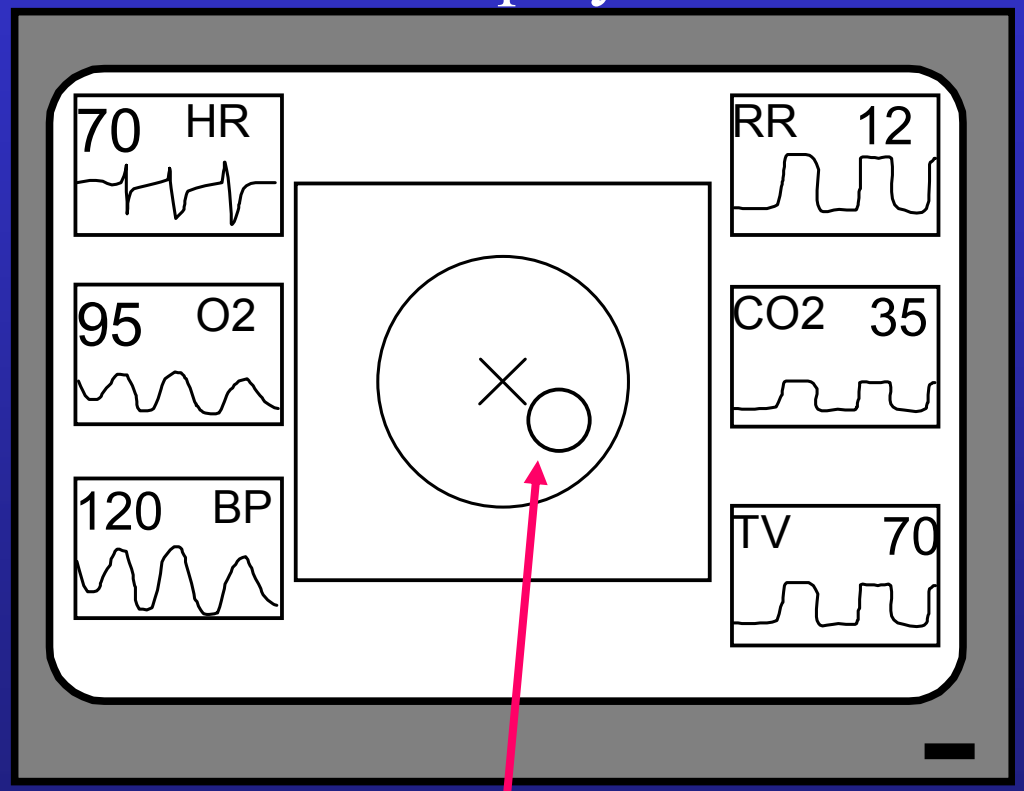
	Pace	**Pitch**	**Timbre**
Circulation:	Heart rate	O2 Sat.	Blood press.
Ventilation:	Resp. rate	CO2	Tidal Vol.

– *<sounds [proposed]>*

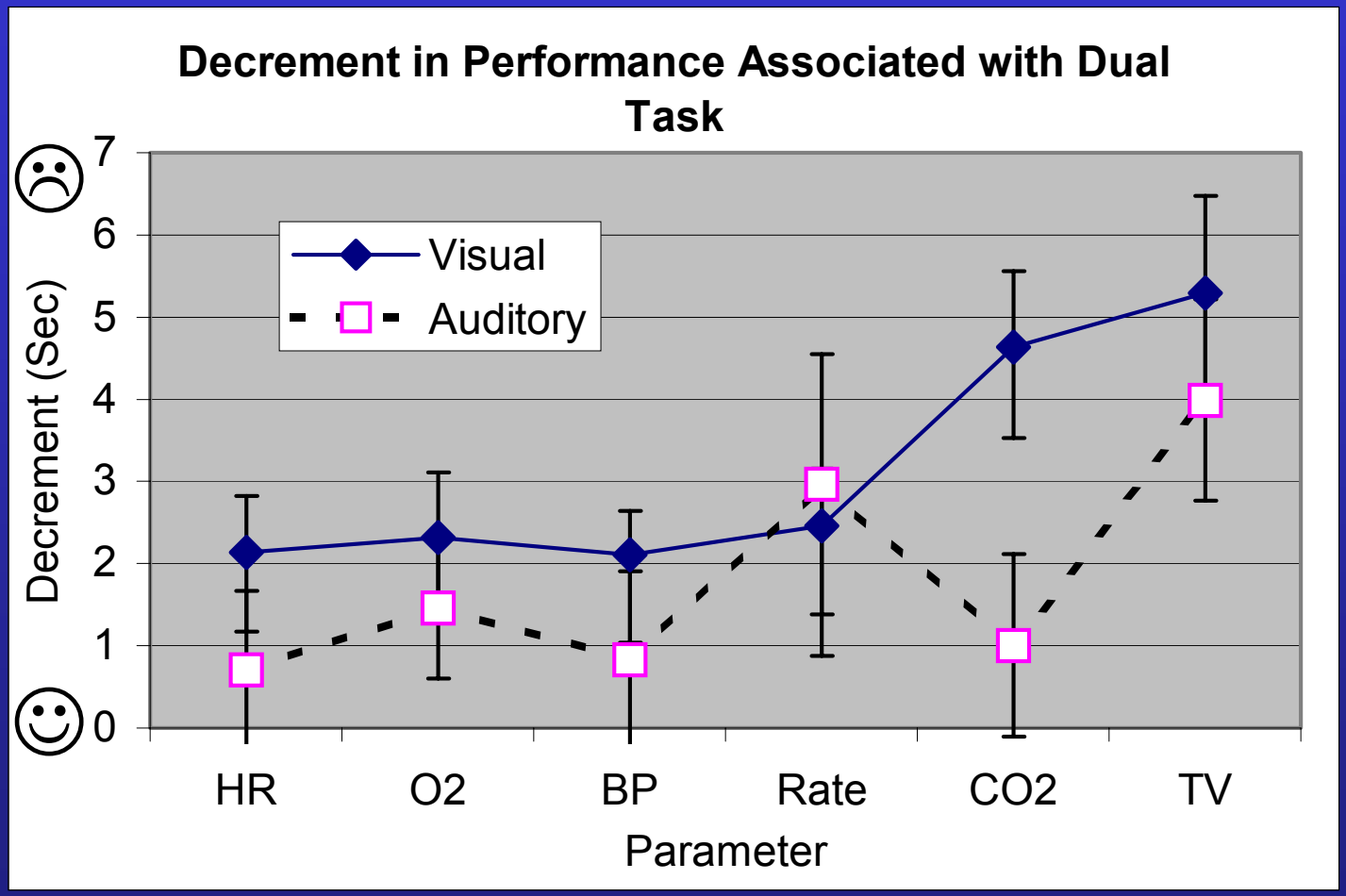
Study 4:

Vital Signs Monitoring and "Patient Care"

New Dual-Task Paradigm for HF

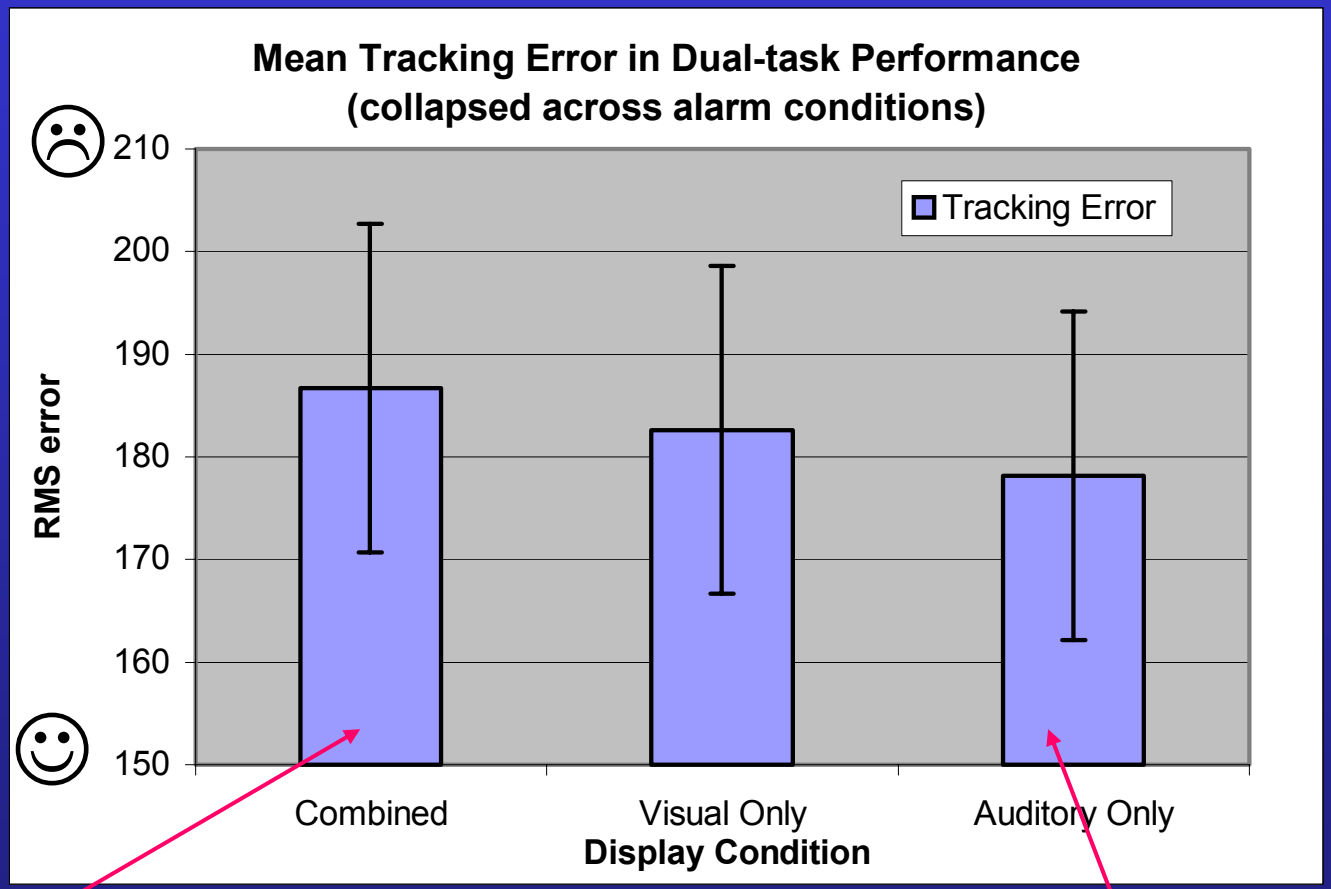


How disruptive is doing two tasks as once? Detecting vital-sign abnormality during "patient care"



• Monitoring the auditory display was disrupted less by dual task than monitoring the visual display [11, 13]

How disruptive is doing two tasks as once? Effects on "patient care" (manual tracking)



[11,13]

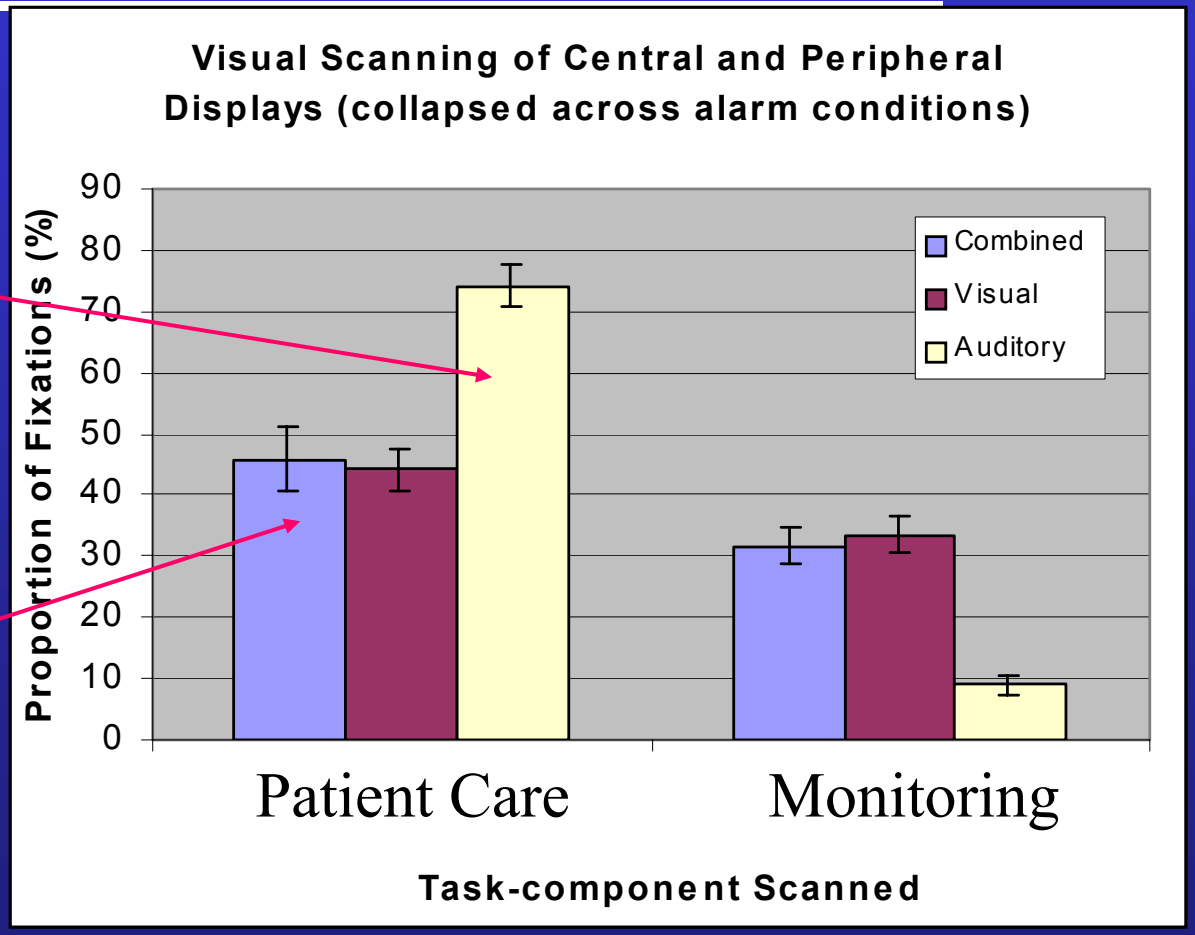
"Redundancy cost" of combined display

Auditory-only displays help focus on the patient

What do people look at? Division of visual attention

Patient care helped by auditory display

Patient care not facilitated by redundant display



[11,13]

Auditory Display Summary

- **Multi-modal benefit: auditory-only display**
  - *best "patient care" (tracking scores)*
  - *smallest dual-task decrement for vital signs monitoring*
- **Redundancy cost:**
  - *Patient care worst with combined display*
- **No redundancy gain:**
  - *Vital signs monitoring not facilitated by redundant display*

Possible Improved Approach

- **Some success for better technology "partner"**
  - *informative*
  - *non-interruptive*
- **Additional approach: Auditory "display" present only during "alarms"**
  - *Reduced 'noise pollution' and redundancy cost, maintain communication*

Interface Design and Patient Safety

- **Insight into complexity of alarm problem**
  - *no quick fixes: combined display may not be an ideal solution at this point*
  - *More questions, and further research needed*
- **Research model: Learn from other domains**
  - *combination of health-care providers with researchers from human factors, psychology, engineering, aviation, nuclear power, etc.*
  - *Mutually beneficial collaborations*
- **Medical device design needs to consider information needs of users for patient safety, functionality, and ease of use**

Conclusions:
Strategies for New Technologies

- Demand better-designed equipment!
- You are designing a work partner – what type of partner you want?
- Make sure the implementation team works closely with users, designers and human factors specialists.
- Iteratively test and improve interface and functionality
  - ***Rome was not built in a day***

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